APPENDIX B -- HISTORICAL VEGETATION DISTRIBUTION ALONG THE NORTHWEST FORK OF THE LOXAHATCHEE RIVER

CONTENTS

Changes in the balance of fresh and salt water appear to have resulted in significant changes in the distribution of freshwater and saltwater vegetation along the floodplain of the Northwest Fork of the Loxahatchee River. While cypress and other freshwater communities can still be found in the upper reaches of the Northwest Fork of the Loxahatchee River, the lower undeveloped portions of the floodplain are now dominated by mangrove forest and subject to daily tidal fluctuations. These anthropogenic alterations within the Loxahatchee River Watershed have been well documented throughout the 1900s.

During 1980-81, McPherson (unpublished) studied the transitional area between the cypress forest community and the mangrove community on the Northwest Fork. In May of 1981, McPherson observed surface salinities of 20 to 30 parts per thousand (ppt) in an area of dead and stressed cypress. In another area of intermediately stressed cypress, he observed surface salinities from 15 to 20 ppt. Shallow groundwater salinities decreased with depth below the land surface and distance from the river with the exception of areas where seepage of freshwater was observed from nearby higher pinelands. Russell and McPherson (1984) had reported that the saltwater-freshwater interface in the Northwest Fork of the Loxahatchee

River moved daily about 0.5 to 1.5 river miles as a result of tides and annually about 3 to 5 miles as a result of seasonal changes in freshwater flow. McPherson and Halley (1996) in their publication, *The South Florida Environment: A Region Under Stress,* documented the encroachment of mangroves, along with the overall reductions in freshwater flows, maintenance of lower groundwater levels, short duration high volume freshwater flows for flood protection, and changes in the quality of runoff.

Between 1979 and 1982, Deuver and McCollum (unpublished USGS) studied tree stress and salinities in the area of transition between the cypress forest and mangrove communities along the Northwest Fork (**Appendix A, Figures A-1 and A-2**). In an examination of cores from 69 cypress trees from 11 sites along the NW Fork, Deuver and McCollum observed that small and poor quality tree rings increased from 22% in 1950 to about 58% and 79% respectively by the late 1970s at sites downstream of Rivermile 9 (RM). At sites upstream of RM 9, the percentage of large "healthy" tree rings increased since 1940 with the exception of a dip during the late 1950s. With regards to salinity, they noted surface salinities ranging 5 to 20 ppt in an area of dead and stressed cypress, while surface salinities in an intermediate stressed cypress area ranged from 2 to 4 ppt. In the upstream healthy area of cypress forest, surface salinities were less than 2 ppt.

Between October 1993 and January 1994, Ward and Roberts (unpublished) examined six vegetative transects on the Northwest Fork of the Loxahatchee River between Indiantown Road (State Road (SR) #706) and the mouth of Kitching Creek (RM 8.0). Generally the density (stems/hectare) of bald cypress (*Taxodium distichum*) increased from downstream (Transect #6, RM 8.5) near Kitching Creek to upstream (Transect #1, upstream of RM 10 just north of State Road #706). A noticeable drop in cypress density occurred at Transect #3 (upstream of RM 10 and just north of Interstate 95), which was heavily populated with pop ash (*Fraxinus caroliniana*), red maple (*Acer rubrum*) and cabbage palms (*Sabal palmetto*). They did not examine the density of mangrove during their study.

Historical Aerial Photography Studies

Alexander and Crook (1975) utilized aerial photographs and groundtruthing to examine plant communities along the Northwest Fork of the Loxahatchee River and Kitching Creek. Plant species lists were compiled for Site 13 (RMs 7-8), Site 14 (RMs 7.0-7.5), and Site 15 (RMs 6.0-6.5) on the Northwest Fork and Site 10 on Kitching Creek. Upon identifying the signature of the most abundant community types, they were able to use photo-interpretation to identify major vegetative communities from a 1940 aerial photograph. Areas of dead and living cypress canopy within a mangrove understory were noted in 1970. They concluded that since 1940, wet prairie and swamp hardwoods had lost ground to pineland and mangrove communities due to a lowering of the groundwater table and invasion of saltwater between RMs 6 and 8. They were able to identify areas of active logging in the aerial photographs, which could explain the loss of mature trees within portions of the watershed. Also, they mentioned the impact of fire, hurricanes and heavy frost on the major plant communities. At RM 6.5, they collected freshwater peat at a depth of 24 inches below the surface. Based on this information, they further concluded that there was no evidence that cypress forest had extended much further downstream than about RM 6. Wanless (written communication, 1982) suggested that RM 6 has experienced brackish conditions for at least the last 4,500 years. Finally, Alexander and Crook (1975) predicted that the mangrove invasion would accelerate, if anthropogenic activities in the upper floodplain of the river further reduced the freshwater head.

Hohner (1994) used aerial photography and satellite imagery to examine vegetative changes in the Loxahatchee Slough between 1940 and 1989. The Loxahatchee Slough is part of the headwaters of the Loxahatchee River. In a comparison of the vegetative classes Forest Land (Hammock), Nonforested Wetland (Wet Prairie), Forested Wetland (Cypress), and Nonforested Wetland (Marsh), she concluded that with geographic information system (GIS) analysis there was a general trend toward dryer hydroperiod vegetation. A portion of the study area, in which water levels were raised to pre-channelization levels in 1979, exhibited a recovery to vegetation communities more characteristic of longer hydroperiods.

Aerial Photographic Study of the NW Fork of the Loxahatchee River

This study examines the displacement of cypress and stream swamp by mangrove forest along the Northwest Fork of the Loxahatchee River and Kitching Creek using historical black and white and color infrared aerial photographs taken over a 55-year period. Color infrared photographs were used for more recent periods. To obtain a more detailed look at changes in freshwater and saltwater communities between 1940 and 1995, District staff divided the river into six segments (Lower NW, Mid NW, Upper NW, Wilson Creek, Kitching Creek, and Island Way Creek) (**Figure B-1**). For a six-decade glance, District staff examined vegetative changes between RMs 6.6 and 8.9 from 1953, 1964 and 1979 black and white aerial photographs in addition to the 1940,1985 and 1995 photographs. This study also re-examined Loxahatchee River vegetative sampling sites originally established by Alexander and Crook (1975) during their investigation of long term vegetation changes in South Florida. The purpose of this study was to document the changes in vegetative coverage and correlate those changes to major events in the watershed.

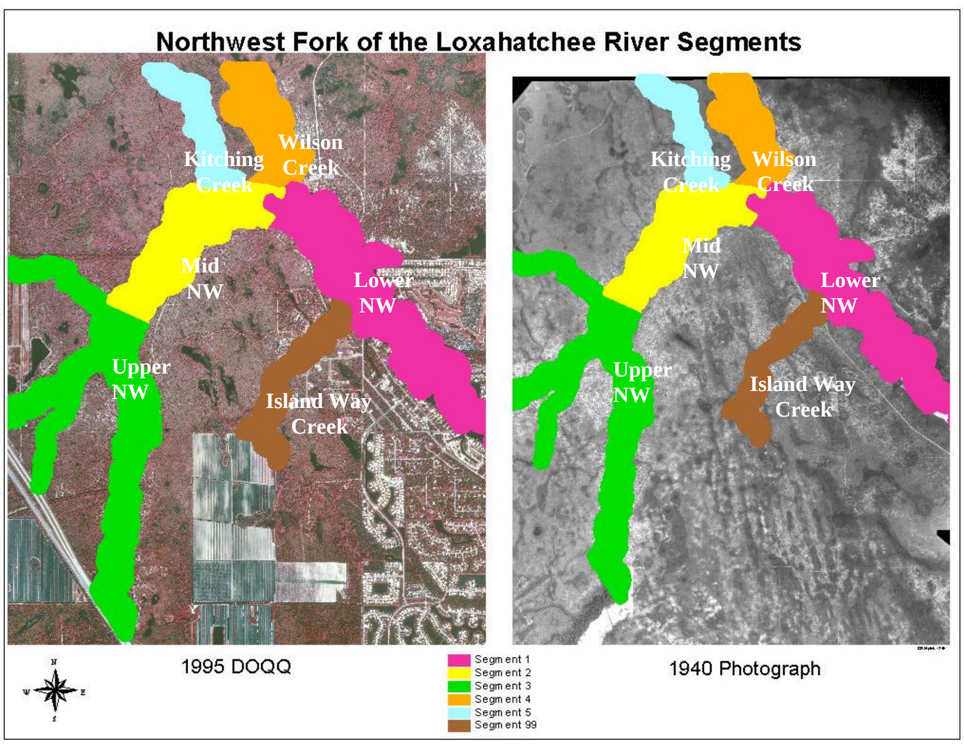
Similar historical aerial photographic interpretation studies have been done on Northern Biscayne Bay, Florida. Harlem (1979) conducted aerial photographic surveys from 1925 and 1976 aerial photographs of the Bay. His work was supplemented with field studies to examine the effects of urban development and natural stresses over time. Maps were created to delineate overall long term changes in developed land, dredged and spoil areas, decreases in vegetative cover, and increases in bulkheaded shorelines. The major changes observed included the expansion of land areas as a result of filling of swamps, the creation of new islands from dredged spoil material, and changes in circulation patterns as a result of inlet and causeway construction.

Methods

Aerial photographic interpretation was first developed for use by the military during the First World War. Other uses included mapping of coastal areas and coastlines for maritime purposes. The use of aerial photographic interpretation in investigating environmental changes over time has increased dramatically as aircraft, cameras, and film technology have improved. The application of aerial photography has advanced along with electronic technology to include multi-spectral and microwave imaging, and the more sophisticated satellite imaging. Historical aerial photographs provide a tool to map the distribution of sub-environments for any photographed year. By comparing a succession of younger age photographs of the same areas, changes can be monitored and documented for rates of change and long term trends. It may also be possible to identify sources of those changes.

This study of the Northwest Fork of the Loxahatchee River utilized black and white aerial photographs from 1940, 1953, 1964, and 1979 and color infrared photographs from 1985 and 1995. Aerials were obtained from the National Archives, the U.S. Department of Agriculture, Consolidated Farms Service Agency, and the National Aerial Photography Program. The 1985 color infrared photographs were obtained from a special flight conducted for SFWMD over Lake Okeechobee and portions of the Loxahatchee River Watershed, while the 1995 photographs were Digital Ortho Quads (DOQQs). The 1940 aerial photographs (Accession Numbers CJF 3-51,17-53, 17-54) were taken on August 21, 1940 at a scale of 1:40,000, while the 1995 aerial photographs (Accession Number NAPP 6966-089) were taken on January 26, 1995 at a scale of 1:40,000. The 1985 photographs were taken by Abrams Aerial Survey Corporation on April 27, 1985 at a scale of 1:400. Eight photographs from the 1985 survey were scanned to produce the floodplain coverage. The 1940 photographs were scanned at a scale of 3' per pixel and georeferenced to the 1995 DOQQ's. The 1995 aerials for the DOQQ's were scanned at a 1 meter-pixel resolution and rectified to meet a 1:12,000 scale accuracy for the quarter quadrangles. All imagery was produced in the State Plane Coordinate System, Florida East Zone, 1983 Datum. For a six-decade glance, black and white photographs from 1953, 1964 and 1979 were examined in addition to the analysis of 1940, 1985 and 1995. Floodplain areas between RMs 6.6 and 8.9 were digitized for the three additional years. Total vegetative community coverage by type and by year was compared over time to quantify changes in vegetative types over this 55-year period. The 1940 and 1995 coverages were further broken down by river segments corresponding to Segment 1 (Lower NW), Segment 2 (Mid-NW), Segment 3 (Upper NW), Segment 4 (Wilson Creek), Segment 5 (Kitching Creek) and Segment 99 (Island Way Creek). The locations of these river segments are shown in **Figure B-1**.

Figure B-1. Location of River Segments



To validate the images produced by the major plant community-types in the floodplains and associated upland communities, groundtruthing and field observations were conducted from a helicopter on October 19, 2000 and November 1, 2000 and from ground surveys on November 14 and 29, and December 12, 2000. Dominant species of plants in the canopy were noted on hard copies of the photographs.

Plant community signatures utilized in this study were adopted from the Florida Land Use, Cover and Forms Classification System (FLUCCS), Florida Department of Transportation, 1985 (**Table B-1**). Color and texture descriptions listed in the reference document were compared with known vegetation from the 1995 aerial to establish the following list of observed classifications:

Vegetative Coverages

- 243 Ornamental Garden
- 300 Rangeland
  - 321 Palmetto Prairies
- 400 Upland Forests
  - 427 Live Oak
  - 428 Cabbage Palm
  - 437 Australian Pine
- 500 Water
- 510 Streams and Waterways
- 600 Wetlands
  - 612 Mangrove Swamp
  - 615 Stream & Lake Swamp
  - 616 Inland Pond and Slough
  - 621 Cypress
  - 641 Freshwater Marshes
- 700 Barren Land
- 740 Disturbed Land

Using these categories, major plant communities were delineated into distinct aerial units characterized by specific tones and textures. Image tones refers to the brightness of an area of background as portrayed by the film in a given spectral region (or in three spectral regions for color or color infrared). Image texture refers to the apparent roughness or smoothness of an image region. Texture is produced by the pattern of highlighted and shadowed areas as an irregular surface is illuminated from an oblique angle. Mature forest appears as rough texture, while agricultural fields appear as smooth texture. Categories such as cypress may be recognized by the distinctive shape of the pin-like crowns of some trees (Campbell, 1987).

Results & Discussion

Comparison of Vegetation Coverages along the Northwest Fork of the Loxahatchee River

Geographically, the Loxahatchee River Watershed can be characterized as sub-tropical with an average daily temperature of 82° Fahrenheit (F.) in summer to an average winter temperature of approximately 66° F. The region receives approximately 60 inches of rain annually. The landscape is topographically divided into two landforms, the Atlantic Coastal Ridge and Eastern Flatlands. Vegetative communities consist primarily of coastal hammock, pine flatwood, seasonal ponds and prairies, freshwater swamp hardwood, and mangrove.

Much of the region remains unurbanized today due to earlier military and agricultural uses. Subsequently, land use changed to large tracts of public conservation and recreation and agricultural lands, and low density 5 to10 acre ranchettes. The Northwest Fork has been provided with additional protection as portions of this water body have been designated as a federal wild and scenic river. The oldest municipality is the Town of Jupiter, which was incorporated in 1925. Neighboring municipalities Juno Beach, Jupiter Inlet Colony, Jupiter Island, Palm Beach Gardens, and Tequesta were all incorporated during the 1950s (**Table B-2**).

1940 Vegetative Communities

The Loxahatchee River Watershed was largely undeveloped in 1940 (**Figure B-2**). According to the 1940 U.S. Census, the Town of Jupiter contained 215 residents (**Table B-2**). Interstate 95 and the Florida Turnpike had not been constructed. The major roads in the area were Center Street, State Road 706 (Indiantown Road), State Road 710 (Beeline Highway), U.S. Federal Highway 1, State Road 708 (Bridge Road) and Northlake Boulevard. Also, the C-18 Canal had not yet been constructed, although evidence has been found of ditching southward to the Loxahatchee and Hungryland Sloughs. The Jupiter Inlet was open in the 1940 photograph, but the presence of sandbars probably reduced the amount of saltwater coming in during high tides. The inlet was not permanently stabilized for navigation until 1947. On the Northwest Fork, incoming tides may have reached upstream past the mouth of Kitching Creek frequently enough to produce a fringe of mangroves along the river ending at RM 7.8 on the northern bank.

The most obvious features of the 1940 aerial photographs are the abundance of wetlands associated with sloughs and wet prairies and the lack of urban development throughout most of the watershed (**Figure B-2**). There are extensive wetlands (prairies and four major sloughs) between Kitching Creek, the North Fork of the river, and Bridge Road in Martin County. Two of the sloughs appear to be connected to the North and NW Forks. These areas would have provided a source of freshwater to the river and estuary that is not present today. Of the four sloughs, only Wilson Creek remains connected to the river today.

Other visible hydrologic characteristics in the 1940 photographs included:

- On the Northwest Fork, Hobe Grove Ditch did not exist but Moonshine Creek was apparent and drained a wetland slough to the north
- No citrus was grown near the river as it is today, but there was extensive land clearing north of SR# 706 on the east side of the Northwest Fork (perhaps for agriculture) and in the vicinity of the Park’s boundary (i.e. location of power lines today)
- A wetland slough connected Jones Creek to Lake Worth Creek (in the vicinity of what is today Frenchmen’s Creek)
- Jones and Sims Creeks were lined with mangroves south of SR# 706
- A ditch was dredged from Loxahatchee Marsh to Limestone Creek (headwaters of the SW Fork). Limestone Creek was later channelized by the dredging of the C-18 Canal in 1957-58. Since 1994, SFWMD has worked to restore upland and floodplain vegetation along the right-of-way downstream of S-46.

- Mangroves bordered the North Fork and transitioned into freshwater vegetation in the vicinity of today's park boundary (north of County Line Road). The floodplain was very narrow in the mangrove areas

Figure B-2. 1940 Loxahatchee River Watershed

- There were very few mangrove islands in the embayment area
- Spoil mounds were evident along Lake Worth Creek and the lower Indian River Lagoon from the dredging of the Atlantic Intracoastal Waterway channel

Table B-3, provides a summary of the major vegetation communities found along the NW Fork of the river in 1940 based on a review of historical black and white aerial photographs, while **Figure B-3** compares the 1940 and 1995 distribution of fresh and brackish water vegetation in the floodplain of the Northwest Fork by river segment. An estimate of the location of Interstate 95 and the Florida Turnpike was made to define the southern boundary of the study area in the 1940 photograph. Unlike the clarity of later black and white and infrared photography, it was difficult to identify plant species other than cypress and cabbage palm within the freshwater communities. In addition, the 1940 photography was taken during the month of August, when all trees would have possessed full canopies, whereas most aerial photography is taken during the winter months when trees, like cypress, are dormant and very distinguishable. Therefore, in **Table B-3**, total acreage of cypress was combined with stream swamp to compare 1940 with the 1985 and 1995 coverages. The category of cypress represents a community dominated by cypress but also may contain red maple, pond apple, pop ash, water hickory, laurel oaks, and bays, whereas the category of stream swamp represents a freshwater community of primarily mixed hardwoods with cypress (present but not dominant). Cabbage palms, which are normally associated with upland communities, are found at tidally inundated to seldomly inundated areas of the floodplain along the NW Fork of the Loxahatchee River. During the 2000 field observations, it was noted that those cabbage palm still surviving in inundated areas did not appear as healthy as those did at higher elevations.

Table B-3 and Figure B-3 show that in 1940, there were about 163 acres of mangroves and 467 acres of cypress dominated freshwater communities, 58 acres of inland ponds and sloughs, 3 acres of cabbage palm, 4 acres of ornamental vegetation and 27 acres of cleared land within the floodplain. Of the total 720 acres of vegetation identified in the 1940 aerial photography, more than 64% was represented by cypress communities while mangroves represented about 22% of the vegetative cover. Disturbed or cleared land represented 27 acres or about 4% of this coverage. Mangroves dominated the floodplain between RMs 4.5 and 6.0 and were present up to RM 7.8. Freshwater communities were present from about RM 6.5 and were dominant upstream above RM 8.0. As mentioned in the book "**Loxahatchee Lament",** the area of ornamental vegetation includes an exotic ornamental plant garden (1.4 acres) established by Mrs. Alice De Lamar prior to 1940. Segments 1 and 2 (Lower and Mid NW Fork) were the most impacted areas in 1940.

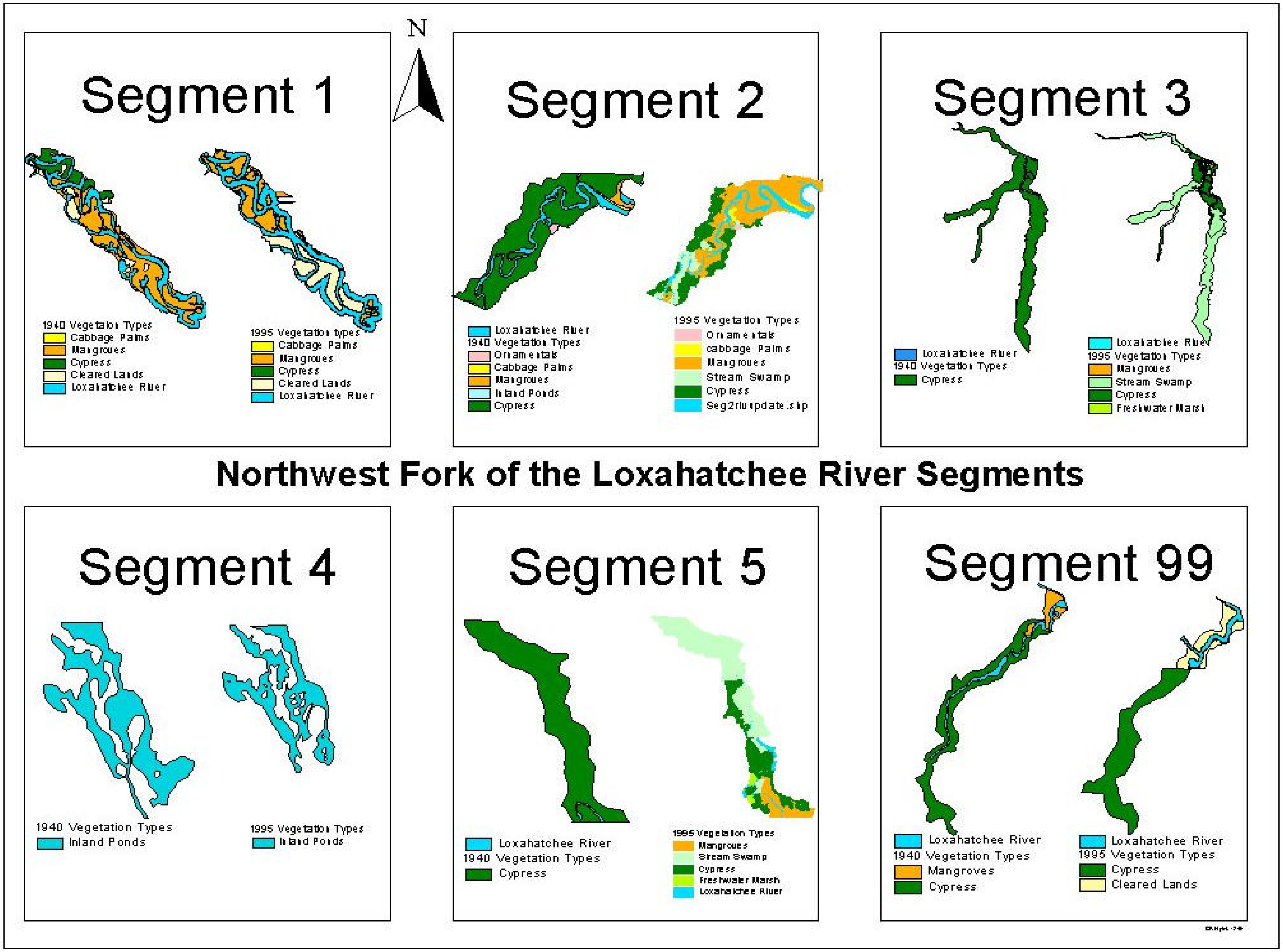


Figure B-3. Comparisons between 1940 and 1995 Coverages by River Segment

1985 and 1995 Vegetative Communities

Beyond the obvious publicly owned lands and agricultural fields, the eastern portions of the Loxahatchee River Watershed were highly urbanized in the 1985 and 1995 photographs. During a 1999 estimate by the U.S. Census, the Town of Jupiter reported a population of 33,925 residents within the city **limits**. Jupiter residents plus neighboring municipalities accounted for a population of 77,484 (**Table B-2**); however, this figure does not include the residents of unincorporated Palm Beach County in the western portion of the watershed. According to Palm Beach Planning and Zoning Department, the 1999 census estimated an additional 10,506 residents in Jupiter Farms and 3,536 in Palm Beach Country Estates. Interstate 95 and the Florida Turnpike stand out as major features that bisect the landscape along with extensive areas of agriculture (primarily citrus and cattle grazing), and the 11,471 acres of Jonathan Dickinson State Park.

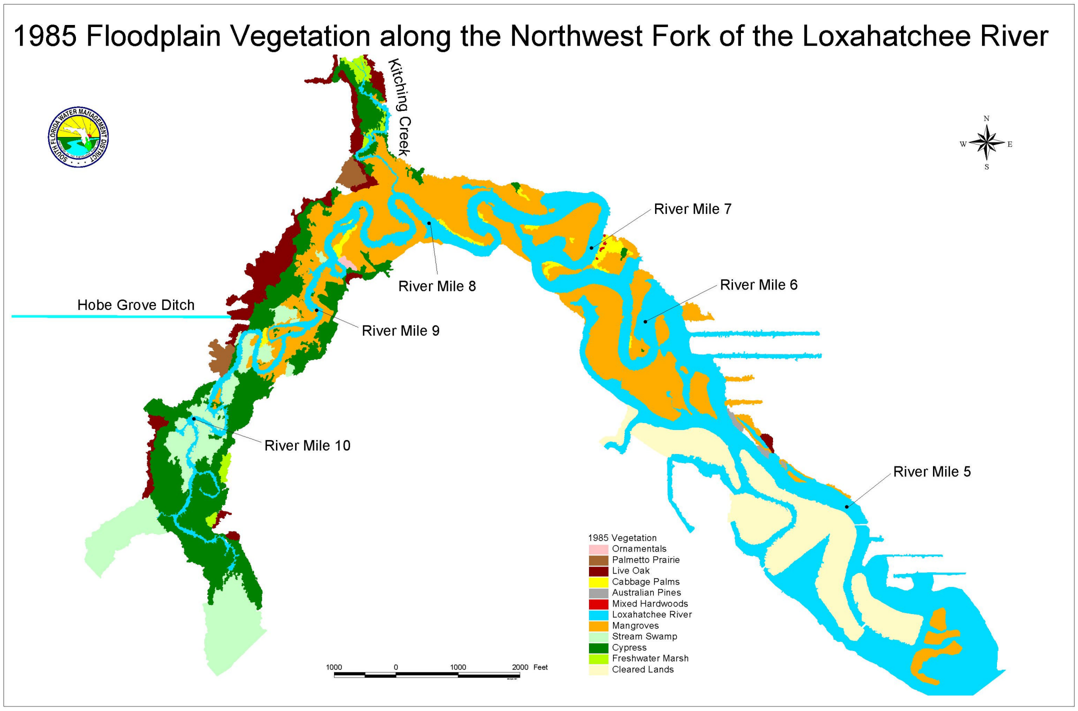


Figure B-4. 1985 Vegetation

Figure B-4 illustrates the 1985 distribution of vegetation within the floodplain, while **Table B-4** summarizes the coverages. Color infrared photography allowed for the identification of a greater number of plant categories and better observation of vegetative changes. In 1985, the floodplain of the NW Fork consisted of 61% (390 acres) freshwater communities and 25% (161 acres) mangroves. Mangroves were dominant between RMs 5.5 and 8.7 and present up to RM 10.4. Freshwater communities were present in the upper elevations of the floodplain from about RM 8.5 and inside all of the creeks. Stream Swamp, which represents a mixed hardwood community of less than 50% cypress, was present upstream of RM 9.3 and within Kitching Creek. Only a few dead cypress trees were noted between RMs 4.5 and 5.5; however, the frequency of dead cypress trees increased between RM 6.8 and 10 with a peak between RMs 8.4 and 8.8.

Figure B-3 illustrates the 1995 distribution of vegetation within the floodplain of the NW Fork by river segment, while **Table B-5** summarizes the coverages. In 1995, the vegetation consisted of 61% (371 acres) freshwater vegetation and 25% (152 acres) mangrove. Freshwater vegetation consisted of stream swamp (197 acres), cypress (129 acres), cabbage palm (4.3 acres), inland ponds and sloughs (39 acres) and freshwater marsh (2 acres). In 1940, mangroves were dominant between RMs 4.5 and 6.5 and were present up to RM 7.8, while mangroves by 1995 had progressed upstream as the dominant vegetation in the floodplain between RMs 5.5 and 8.7. Near the mouth of Kitching Creek, mangroves appeared as forests whereas further upstream they appeared as understory to a cypress/cabbage palm canopy. Just downstream of the mouth of Moonshine Creek (RM 9.8), mangroves expanded slightly along the shoreline since 1985. Also, stream swamp in this area contained scattered red mangroves growing concurrently with pondapple, while exotic java plum trees (*Syzygium cumini*) were growing concurrently with popash and dahoon holly. Trapper Nelson supposably introduced java trees along the river.

Overall, there were no major changes in vegetation between 1985 and 1995. Between 1940 and 1995, most of the observed changes were within the Lower NW and Mid NW segments. Freshwater communities were present in all segments, but primarily in the Upper NW segment. Disturbed and/or Cleared Lands were present primarily in the Lower NW segment. Those Disturbed Lands that were not developed eventually became mangrove communities after first becoming brackish water marsh according to local knowledge of the area.

The most striking features noted in comparing the 1940 with 1985 and 1995 was the dredge and filling of mangrove islands between RMs 4.5 and 5.5 and the loss of floodplain adjacent to the NW Fork. Invasion of upland species (i.e. saw palmetto, slash pine, etc.) and development, including the construction of bulkheads along both shorelines of the estuary and lower NW Fork of the river, and heavy scouring of the land and oxbows are some factors contributing to the overall loss (113 acres) of floodplain between 1940 and 1995 (**Figures B-3 and 4**).

Between 1940 and 1995, mangroves exhibited losses and gains in total coverage (**Tables B-2, 3 and 4**). Approximately 84 acres of mangroves were lost due to development of former mangrove islands between RMs 4.5 and 5.5. Mangroves gained another 149 acres from re-establishing in cleared lands (6%) and from invading freshwater communities (32%). The gains in coverage occurred primarily between RMs 6.0 and 8.5. And, it appears that mangroves had taken over areas that were formerly brackish water marsh. Approximately 165 acres of mangroves remained unchanged over the 55-year period.

There were no overall gains in freshwater vegetation over the study period. Infrared photography allowed for the identification of freshwater marsh associated with the wider floodplain areas. It was also noted in the field that many of the remaining freshwater marsh areas and Wilson and Moonshine Creeks have been invaded by the exotic old-world climbing fern, *Lygodium microphyllum*. There were net losses of 149 acres of freshwater habitat (i.e. mangroves gained), primarily between RMs 6.5 and 7.8. Within the remaining freshwater communities along the open river (RMs 9.0 to 10.5) there were changes in the signature of the canopy. Whereas the 1940 black and white photographs had exhibited a very uniform canopy among swamp hardwood areas, the 1985 and 1995 photographs exhibited a canopy of more varying heights, colors and textures. Field observations and geographical coverages revealed that while there were remaining areas of greater than 50% cypress, other areas consisted of a mixture of water tolerant hardwoods including red maple (*Acer rubrum)*, water hickory (*Carya aquatica)*, laurel oak (*Quercus laurifolia)*, pond apple (*Annona glabra)*, popash (*Fraxinus caroliniana)*, dahoon holly (*Ilex cassine)*, and swamp bay (*Persea palustris)*. These areas were designated as "Stream Swamp" in the 1985 and 1995 coverages.

GIS analysis of the 1985 and 1995 distribution of mangroves and freshwater coverages in the Hobe Grove Ditch and Cypress Creek areas reflects that freshwater communities dominated by cypress appear to be more closely associated with wider floodplains suggesting that there may be less species competition and less water stress associated with these areas. Two factors may contribute to this observation, distance from the riverbed and potential saltwater encroachment, and rising elevations within the floodplain between the riverbed and upland areas.

Other visible hydrologic characteristics in the 1995 photographs included:

- The SW Fork was channelized between 1957 and 1958 to create the C-18 Canal, which redirected water from the NW Fork to the SW Fork. Discharges to the river are controlled at the S-46 Structure.
- C-14 and the G-92 Structure were constructed in 1974 to redirect water from the SW Fork back to the NW Fork.
- Over 3,000 acres of citrus groves have been planted west of the NW Fork.
- Hobe Grove Ditch was dug through uplands to provide flood control for the citrus groves during the 1960s. Surface water flowing from this area during dry periods is now retained to maintain the water table for irrigation wells.
- Most of the remaining inland ponds and sloughs appear to be much smaller in size than in the 1940 photographs denoting a change in vegetative type from wetlands to transitional or upland species.

A Six-Decade Vegetation Analysis of the NW Fork of the Loxahatchee River

For a more detailed analysis of observed vegetation changes over time, District staff analyzed black and white aerial photographs taken of the river between river miles 6.6 and 8.9 during the years 1940, 1953, 1964 and 1979. These early vegetation coverages were also compared to more recent infrared Digital Ortho Quad photographs taken from the watershed in 1985 and 1995. River miles 6.6 to 8.9 represent that area of the river where the majority of vegetative changes have taken place over the past 55 years. The six-decade analysis of vegetative changes **Figures 15 and 16** (in the main document) clearly show the encroachment of mangroves between RMs 6.6 and 8.9.

1940's Vegetation Coverage: In **Figure 16**, the 1940's distribution of the freshwater communities that were dominated by cypress is color-coded green, while mangroves are color- coded as orange. This coverage represents our earliest photographic record of the distribution of cypress communities prior to permanent opening of the Jupiter Inlet in 1947. Cypress communities extended downstream as far as RM 5.8. Mangroves are also present in 1940 photography extending upstream to RM 7.8. The presence of mangroves along the Lower NW Fork of the river at this point in the river's history may be the result of several factors. Prior to 1947, the inlet opened and closed periodically. During periods when the inlet was open, saltwater may have had the opportunity to penetrate the lower portion of the river allowing mangroves to become established. Other factors that may have contributed to increased salinity levels within the estuary and lower NW Fork prior to 1940 include: (a) construction of the Intracoastal Waterway in 1928 that linked the St. Lucie Inlet with the North Lake Worth Inlet, (b) USCOE dredging of the inlet and lower estuary in the 1930's, and (c) construction of a small agricultural ditch that diverted water from the Loxahatchee Slough marsh to the SW Fork of the river.

1953 Vegetation Coverage: **Figure 16** also shows the distribution of freshwater and mangrove communities in 1953. As shown in the photography, mangrove coverage increases substantially in comparison to the 1940 photography, while the cypress community coverage decreased. These major changes in river vegetation correspond to the opening of the Jupiter Inlet in 1947, which permanently changed the lower estuary from a freshwater/brackish water system to a salinity regime more characteristic of estuarine conditions. In addition, back-to-back hurricanes of the late 1940's and their associated storm surges may have blown mangroves seeds up river and accounting for some of the mangrove colonization shown in the 1953 photography.

1964 Vegetation Coverage: The 1964 photography shows additional loss of the cypress community in favor of mangroves. By 1964, mangroves had colonized the NW Fork of the river as far as RM 8.7 and into the mouth of Kitching Creek. These losses of floodplain swamp and increase in mangrove coverage correspond with two major drainage and development projects within the watershed. In 1957-58, the C-18 canal was constructed to drain the central portion of the Loxahatchee Slough. This project diverted flow away from the NW Fork to the SW Fork, thereby reducing the freshwater head that could prevent saltwater intrusion during low rainfall periods (McPherson et al. 1982). In addition, during the early 1960's a developer also dredged and filled a number of mangrove islands within the lower portion of the river and cut a channel (10-15 ft deep) through the sandbar ("S-bar") that historically provided a natural saltwater barrier to upper reaches of the river (***Loxahatchee Lament***). As a result of these two projects, saltwater could now more freely penetrate the NW Fork of the river during low flow periods.

1979 Vegetation Coverage: The 1979 photography shows the continued decline of the cypress community and increase in mangrove coverage in response to past drainage and development projects within the watershed. These declines correspond with the continued operation of the C-18 canal which essentially eliminated freshwater flow from the

Loxahatchee Slough to the NW Fork from the time the C-18 canal project became operational (early 1960's) until the construction of the G-92 structure in 1974. In addition, dredging of the central embayment area (McPherson 1982), combined with oyster bar removal projects (Chiu 1975), and replacement of the A1A Bridge over the Loxahatchee River are thought to have improved tidal flushing of the estuary. These projects may have also played a role in allowing saltwater to further penetrate the lower portion of the river during dry periods. **Figure 2** (main document) also shows that during the 1970's, the region experienced a number of below normal rainfall years (1971, 1972, 1973, 1975, 1976, 1977 and 1979) which may have also contributed to the river's saltwater intrusion problems.

1985 Coverage: The 1985 photography represents the distribution of vegetation along the river at the time it was designated as Florida's first Wild and Scenic River. At this point in time mangroves were identified as far upriver as RM 10.4 although they were only dominant between RMs 5.5 and 8.7.

1995 Coverage: There was very little change between the 1985 coverage and the 1995 coverage. The 1995 coverage reflected the fact that above RM 9, mangroves expanded only from the areas that were occupied in 1985. This limited encroachment may be attributed to the fact that in 1987 additional culverts and operational criteria were added to G-92 to reconnect the Loxahatchee Slough with the NW Fork resulting in more water being added to the NW Fork (**Figure 1,** main document). **Figure 1** illustrates that on average an increase of 30 cfs was delivered through G-92. Therefore, fresh and saltwater communities may be stabilized for now.

These observations are probably related to hydrological modifications constructed on the SW Fork of the Loxahatchee River in the late 1950s. Between 1957 and 1958, the District channelized the SW Fork and constructed the S46 Structure and C-18 Canal which diverted water from the NW Fork to the SW Fork for flood control. It is interesting to note that since the 1974 construction of the G-92 Structure and modifications to the NW Fork riverbed, vegetative communities appear to have stabilized (i.e. 1985 and 1995 vegetative coverages).

Sklar and Hutchinson (1993) noted similar effects on the growth of tidal freshwater cypress in South Carolina. They concluded that cypress tree growth was related to the cumulative influence of regional rainfall amounts, saltwater intrusion, and periods of low river discharge. Their results suggested that increasing river discharge would increase cypress growth by flushing and preventing tidally-driven saltwater intrusion. Their model predicted that cypress trees in tidally dominated freshwater marshes could die because of increased salt stress within 50 years if sea level rise were to exceed 4-5 millimeters per year.

Comparisons with 1970s River Vegetation Studies

The 1973 field observations of Alexander and Crook (1975) provide a historical record of the existing floodplain vegetation in several locations along the Northwest Fork and Kitching Creek circa 1970. In Alexander and Crook's (1975) study, Site

10 was located on Kitching Creek, while Sites 13, 14, and 15 were located on the Northwest Fork **(Figure B-5)**.

A comparison of our interpretation of the 1940 photography revealed similar results from Alexander and Crook's 1940 interpreted drawings. Alexander and Crook (1975) identified Site 10 as a swamp hardwood dominated by water oak, maple, ash, and pond apple. Sites 13 and 14 were identified as mangrove river communities, while Site 15 was interpreted as a cypress canopy with a mangrove understory. In our interpretation of these same areas (**Figure B-5**), Sites 10 and 15 were still swamp hardwoods, while Site 13 was predominately cypress with a small amount of mangrove at the southern tip. Site 14 was predominately mangrove with some cleared land. Therefore, there were some slight disagreements in the vegetative coverage of Site 13.

For interpretation of their 1973 field observations, Alexander and Crook used 1970 black and white aerials for background. Sites 14, 15, and most of Site 13 were shown as mangrove river communities. Within Site 10, swamp hardwoods were shown to be present just outside of the mouth of Kitching Creek. Field surveys of these same areas were groundtruthed by District staff in November 2000. Their results recorded the following changes in river vegetation:

- Site 10 – (Kitching Creek) mangroves are present up to the second bend in the creek and occur further upstream as understory. Freshwater communities were a mixture of cypress, stream swamp, and freshwater marsh. The largest freshwater marsh area appears to be a mixture of small pond apple, cypress, sawgrass and fern, which is indicative of an area that has been historically lumbered.
- Site 13 - This site is almost completely mangrove. A small remnant of the live cypress population remains on the northern boundary adjacent to the uplands, probably due to distance from the riverbed and influence of the adjacent ground water.
- Site 14 – This site is a large red mangrove island with leather fern and *Crinum americanum* (string lily) understory. It has not changed with the exception that the tree heights no longer reach 30 feet due to impacts from past freezes and storms.
- Site 15 – This site is predominately mangrove with live cypress remaining along the northeastern ridge. Concentrated areas of cabbage palm were observed on another ridge area to the west.

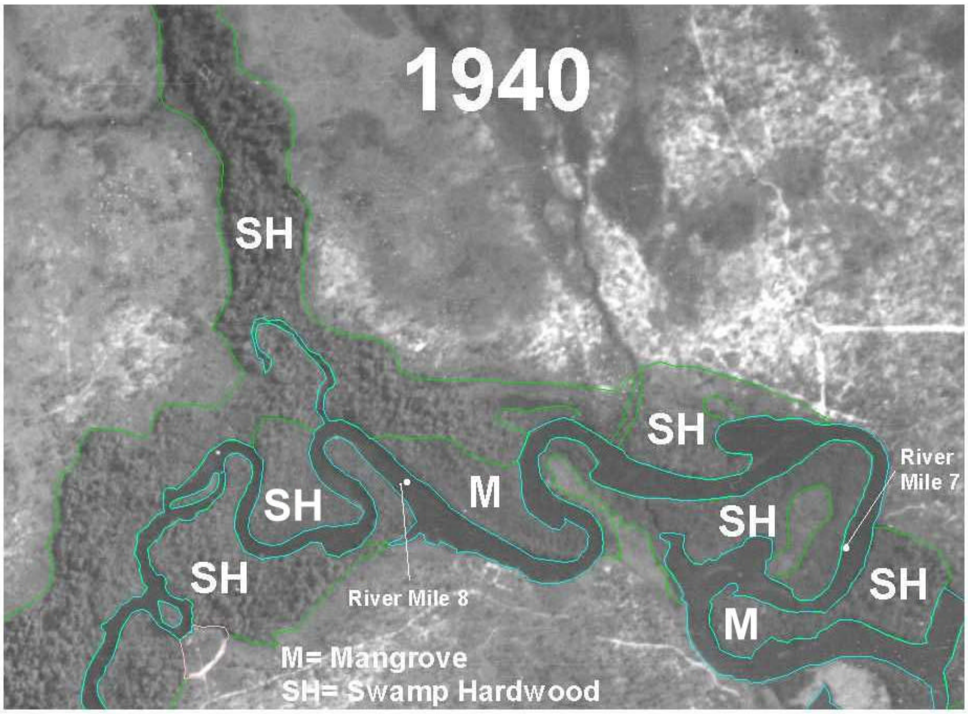
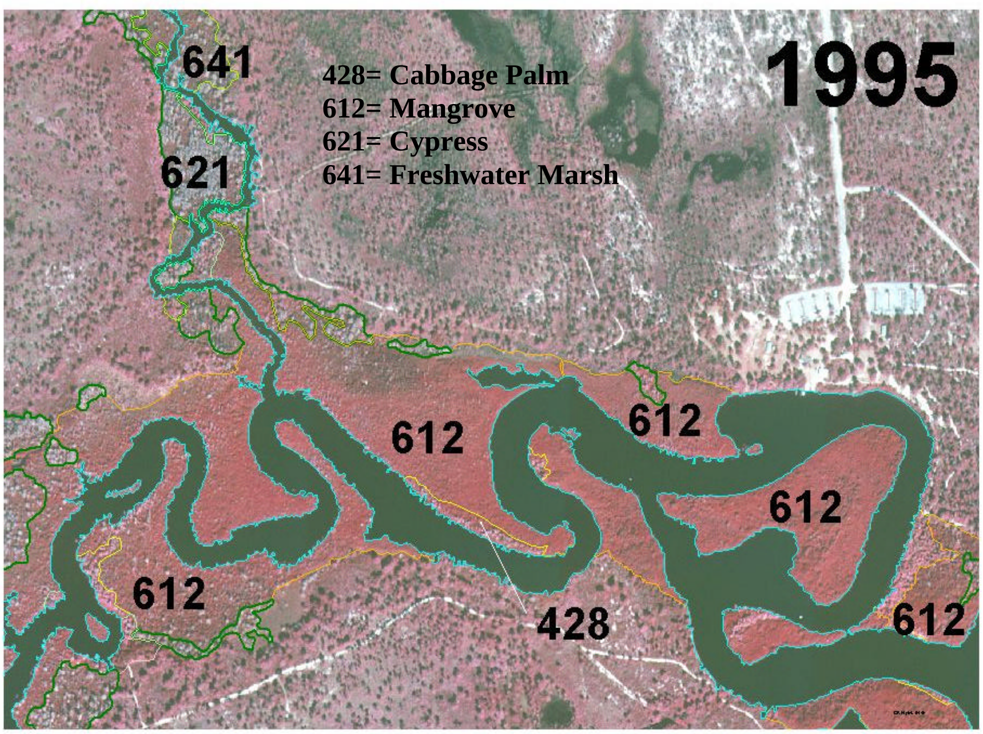


Figure B-5. Comparison with Alexander and Crook's 1975 Vegetation Study



A Discussion of the Impacts of Hydrological Alterations and Meterological Events on Vegetative Changes

Odum et. al. (1982) noted that one generally unrecognized side effect of lowered freshwater flow and saltwater intrusion has been the inland expansion of mangrove forest. The examples that were given included the mangrove borders of Biscayne Bay and much of the Everglades. These forests have expanded inland since the 1940s in conjunction with man's alteration of surface and groundwater flows.

Red mangroves are particularly very successful invaders. Their rod-shaped propagule promotes very efficient tidal transport, and they have the lowest seedling mortality rate compared to other mangrove species (Rabinowitz, 1978a). Davis (1940) noted that floating red mangrove propagules remain viable up to 12 months. In addition, Rabinowitz (1978b) observed that red mangrove seedlings can become established under an existing, dense canopy and then due to their superior embryonic reserves, are able to wait for months for tree fall to open up the canopy and present an opportunity for growth.

The opening and closing of Jupiter Inlet, and the reduced inflows of surface water, and the subsequent drop in the groundwater table has promoted the distribution of mangroves and taken its toll on the freshwater habitat of the Northwest Fork of the Loxahatchee River. The altered saltwater wedge has produced major changes in vegetative communities. In many areas, mangroves now dominate habitat that was formerly dominated by freshwater cypress and has produced additional changes within remaining freshwater communities. Urban development within the headwaters and the major tributaries will continue to reduce freshwater inflow and make any efforts towards preserving this historical flora more difficult.

Hurricanes have affected the watershed by producing rises in tidal levels, opening and closing of inlets, changes in topographical and land contour and by producing severe physical damage to vegetation. Hurricanes have also been known to spread plant propagules over long distances with their waves and high tides. Major hurricanes and tropical storms occurred in the vicinity of the Loxahatchee in 1898, 1903, 1924, 1926,1928, 1933, 1948, 1949, 1964, and 1979. The 1903 storm created an 8-foot storm surge in Jupiter, while Hurricane David in 1979 created a 5-foot surge with winds gusting at 85 miles per hour (mph). Winds of 153 mph were recorded at the Jupiter Lighthouse during the 1949 storm, which passed through Delray Beach (Barnes, 1998).

Severe droughts were recorded in 1937/38, 1943/44, 1950/51, 1955/56, 1960/61, 1966/67, 1970/71, 1980/81,1989/90, and 2000/01. Droughts effect vegetation through "water stress" and saltwater intrusion. Richardson (1977) stated that only isolated stands of cypress exist in places that at one time were extensive forests in Palm Beach County. Virtually no seed germination is taking place in coastal strands because of the lowered water level. Cypress need a hydroperiod for a number of months before germination may take place. Also, Pezeshki et.al. (1987) observed that flooding one-year old bald cypress seedlings above 2ppt. reduced CO_2 fixation by 40%-65% and net photosynthesis by 51-70%. All saline treatments resulted in leaf injury with greater damages at higher salinities. Their study suggested that saline water produces an excess accumulation of sodium and chloride, which may affect different plant processes in cypress.

Historical heavy frost winters were reported in 1939-40, 1957-58, 1962-63 and 1964-65 (Alexander and Crook, 1975) and in 1977, 1983, 1985 and 1989 (Florida Department of Environmental Protection, 2000). Evidence of a major meterological event was apparent from infrared aerial photographs taken during a special flight for South Florida Water Management District in April 1985. Mangroves along the Northwest Fork were defoliated and trees of 30 feet or more exhibited broken branches and trunks. The average monthly air temperatures for January and February 1985 had fallen to 46º and 52º F, respectively with temperatures ranging as low as 25°F (U.S. Department of Commerce, Climatological Data: Florida). Mangroves do not tolerate temperature fluctuations exceeding 18° F or temperature below freezing for any length of time (Odum et. al, 1982). They may defoliate after exposure to 45°F or less. This may explain why mangroves along the Northwest Fork of the Loxahatchee River are not reaching the height of mature mangroves, which can range between 60 and 80 feet.

Although mangroves have taken over a considerable amount of the downstream historical coverage of freshwater vegetation along the Northwest Fork of the Loxahatchee River, the Wild and Scenic River segments of the waterway continue to be a valuable natural resource and tourist attraction with both mangrove and cypress habitats. As in coastal areas, mangroves still provide shoreline stabilization, wildlife habitat, and aesthetic values.

Conclusions

Results of the comparison of 1940, 1985, and 1995 aerial photographs showed the following:

- Reductions in total acreage of the river floodplain between 1940 and 1995, which were attributed to severe scouring of the riverbed, bulkheading, and loss of the wetland vegetation to transitional and upland species. Most of the vegetative changes occurred in the lower and middle segments of the NW Fork (RMs 5 through 10).

- The 1940 aerial photography revealed an abundance of swamp, wetland prairies, inland ponds and sloughs, and mangroves along the river. Freshwater communities dominated the vegetative coverage of the NW Fork representing 73 % of the coverage, while mangroves represented 22%.

- By 1985, much of the watershed had been developed with the exception of Jonathan Dickinson State Park. Freshwater communities represented 61% of the total coverage while mangroves represented 25%. Mangroves were present up to RM 10.4 and experienced a 1% decrease in total coverage due to the urbanization of islands within the floodplain. Freshwater communities decreased by 26 %.

- By 1995, freshwater communities had decreased by 30 %, while mangroves decreased by 7%. Minor differences (-5% freshwater and –6% mangroves) in vegetative coverage occurred between 1985 and 1995. Following a delayed response to the 1957-58 construction of the C-18 Canal and Structure S-46, vegetation within the floodplain of the NW Fork may have responded to increases in rainfall during the 1990s and the improvements to the G-92 Structure in 1986. These two factors may have stabilized the advance of mangroves and saltwater intrusion.

• Mangroves exhibited both gains and losses over the 55-year period. Approximately 84 acres of mangroves were lost due to the development within the floodplain, while mangroves gained coverage (149 acres) by taking over freshwater communities and re-establishing in areas of cleared lands.

• GIS analysis and mapping of fresh and salt tolerant communities reflected an increase in species diversity (i.e. stream swamp versus cypress and mangrove communities) along the immediate river corridor upstream of RM 9. Areas dominated by cypress appear to receive groundwater flow from uplands and wider floodplains, which protect their roots from saltwater.

• An analysis of six decades of change revealed that most of the mangrove encroachment occurred between 1953 and 1979, which also correlates to the small and poor quality tree rings observed by Deuver and McCollum in 1975. Also, this timeframe correlates to a period in which the inlet had been stabilized and freshwater flow had been redirected from the NW Fork to the SW Fork of the river for flood control.

• Comparisons of Alexander and Crook's 1975 investigations and the current investigation revealed similar coverages for all but Site 13 for the 1940 vegetative coverage. Both studies observed a steady increase in the invasion of mangroves along the NW Fork and Kitching Creek.

Any future efforts to restore the freshwater hardwoods and cypress communities on the floodplain of the NW Fork of the Loxahatchee River need to consider the many and diverse resources and functions that need to be protected in the river and floodplain, the overall availability of freshwater throughout the watershed, and the potential for connecting this watershed to other basins and regional resources. In addition, structural changes to the river or estuary may provide viable alternatives that need to be considered and analyzed.

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Table B-1. Major Plant Communities and their Signatures for Color Infrared Photographs

Major Plant Communities	Signature	Vegetation	Hydrology/Soils
300 Rangeland 321 Palmetto Prairies	Bright pink, stippled appearance	Saw palmetto (*Serenoa repens)* is the dominant species. Other potential species: bluestems (*Andropogon spp.)*, panic grasses (*Panicium spp.*), fetterbush (*Lyonia sp.*), gallberry (*llex glabra*), and wax myrtle (*Myrica cerifera*)	Good drainage, seldom inundated
400 Upland Forest 428 Cabbage Palm	Dull, medium red color return with a predominantly fluffy and irregular crown texture with individual crowns discernable	cabbage palms with live oaks and vines	Rarely inundated/ fine sands well to somewhat poorly drained
500 Water 510 Streams and Waterways	black color for rivers streams, creeks, canals and other water bodies		
600 Wetlands 612 Mangrove Swamp	Smooth "cottony" red with generally even height* Areas of stress may appear as bright greenish color with a rough or stipple texture	Dominated by red, white or black mangroves (red towards the water's edge, blacks toward the landward side, whites more landward Other species Buttonwood, seagrape, palms, brazilian pepper, cocoplum	Permanently to tidally flooded/ very poorly drained organics or saline sands
615 Stream & Lake Swamps	Varying size canopies of irregularly shaped crowns from very pin-like (cypress) to mid-size fluffy and cottony overlapping crowns of broad leaf deciduous hardwoods. Cypress greyish green other hardwoods red color returns	Dominated by a mixture of water tolerant hardwoods including red maple, water oak, sweetgum, willows, water hickory, bays Cypress present but not dominant	Seasonal inundation depending upon weather cycles/ Soils mixture of sand, organics, and alluvial materials
616 Inland Ponds & Sloughs	Similar return as 615; however, these areas are found in depressions (ponds) and poorly drained defined drainages (sloughs) not associated with rivers or creeks	Dominated by cypress, red maples, willows with no single species dominating	Semi-permanent or permanent hydroperiods with a few inches of slowly moving water/ Soils highly organic sands or layered
621 Cypress	gray or gray-green color, narrow, densely packed crowns Tallest trees near the center with younger smaller trees along the edges	Dominated by cypress bald or pond Other species: red maple, pond apple, pop ash, water hickory In drier sites laurel oaks, sweet gum and bays	Semi-permanent or permanent hydroperiods/Poorly or very poorly drained, high in organics with peat layer of varying thickness on the surface
641 Freshwater Marshes	Variable, black open water, areas of faint pink	Dominated by herbaceous vegetation including	Seasonally to permanently flooded,

	to white return (floating aquatic vegetation), other vegetation pink to red range producing a smooth to stippled texture Sawgrass and cattail greenish to greenish-white return	maidencane, common reed, cordgrass, bullrush, sawgrass and cattails with some pickerelweed and arrowhead	may dry out during droughts/ Very poorly drained, mineral or organic

*We noted that darker tones of red within the mangrove community appeared to be taller/older trees that had not been as impacted by past freezes. These areas could be found generally in the interior of the communities and had perhaps been shielded from the colder temperatures and stronger winds.

Table B-2. Population as Reported in the U.S. Census in the Loxahatchee River Watershed

Municipality	**Year**						
	1940	**1950**	**1960**	**1970**	**1980**	**1990**	**1999***
Juno Beach	-	-	249	747	1,142	2,172	2,903
Jupiter	215	313	1,058	3,136	9,868	24,907	33,925
Jupiter Inlet Colony	-	-	242	396	378	405	416
Jupiter Island	-	-	114	295	364	549	561
Palm Beach Gardens	-	-	-	6,102	14,407	22,990	34,557
Tequesta	-	-	199	2,642	3,685	4,499	5,122
Total	**215**	**313**	**1,862**	**13,318**	**29,844**	**55,522**	**77,484**

*Estimated by Bureau of Economic and Business Research, University of Florida
Incorporation Dates:
Juno Beach 1953
Jupiter 1925
Jupiter Inlet Colony 1959
Jupiter Island 1953
Palm Beach Gardens 1959
Tequesta 1957

Table B-3. Vegetative Coverage for 1940

1940 VEGETATION	**COVERAGE (acres)**	**PERCENT TOTAL**
Freshwater Plant Communities		
Cypress	467.21	64.04%
Inland Ponds and Sloughs	58.55	8.02%
Cabbage Palm	3.08	0.42%
Ornamental	1.44	0.20%
Sub-total	530.28	72.68%
Salt Tolerant Plant Communities		
Mangrove	163.06	22.35%
Other		
Disturbed or Cleared Lands	26.82	3.68%
TOTAL	**720.16**	**100%**

Table B-4. Vegetative Coverage for 1985

1985 VEGETATION*	COVERAGE (acres)	PERCENT TOTAL
Freshwater Plant Communities		
Cypress	139.18	21.90%
Stream Swamp	199.38	30.37%
Inland Ponds & Sloughs	38.63	6.10%
Freshwater Marsh*	5.39	0.85%
Mixed Hardwood	0.15	0.02%
Cabbage Palm	7.38	1.16%
Ornamental	0.70	0.11%
Sub-total	390.81	61.49%
Saltwater Tolerant Plant Communities		
Mangrove	160.94	25.32%
Other		
Disturbed or Cleared Lands	83.77	13.18%
Live Oak*	31.04**	-
Australian Pine*	*0.13***	-
Palmetto*	*6.73***	-
TOTAL	**635.52**	**100%**

*Coverages of Cypress, Inland Ponds and Sloughs and Stream Swamps in portions of Kitching and Moonshine, and Island Way Creeks, and a segment of the river below Trapper Nelson's were estimated from the 1995 photograph; because, these areas were not flown and photographed during the1985 aerial survey. These coverages were validated through the examination of a 1984 black and white photograph.

** These categories were not included in the total coverages because they were above the river floodplain.

Table B-5. Vegetative Coverage for 1995

1995 VEGETATION	**COVERAGE (acres)**	**PERCENT TOTAL**
Freshwater Plant Communities		
Cypress	128.65	21.20%
Stream Swamp	197.01	32.47%
Inland Ponds & Sloughs	38.63	6.37%
Freshwater Marsh	1.89	0.31%
Cabbage Palm	4.30	0.71%
Ornamental	0.64	0.12%
Sub-total	*371.12*	*61.17%*
Saltwater Tolerant Plant Communities		
Mangrove	152.00	25.05%
Other		
Disturbed or Cleared Lands	83.61	13.78%
TOTAL	**606.73**	**100%**